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NASA TECHNICAL TRANSLATION NASA TT F-15,832

A CONTACTLESS MEASUREMENT SYSTEM FOR CONTINUOUS RECORDING OF TEMPERATURES ON ROTATING PARTS, ESPECIALLY IN ELECTRICAL MACHINES

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Translation of "Kontaktlose Messeinrichtung zum kontinuierlichen Erfassen von Temperaturwerten auf rotierenden Teilen, besonders bei elektrischen Maschinen". AEG-Telefunken, Technische Mitteilungen, Vol. 63, No. 7, 1973, pp. 278-284. A74-22499.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D. C. 20546 AUGUST 1974

22

STANDARD TITLE PAGE

1. Report No. NASA TT F-15,832	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle A CONTACTLESS MEASUREMENT SYSTEM FOR CONTINUOUS RECORDING OF TEMPERATURES ON ROTATING PARTS, ESPECIALLY IN ELECTRICAL MACHINES		5. Report Date August 1974
		6. Performing Organization Code
7. Author(s) W. Raasch and D. Schein		8. Performing Organization Report No.
		10. Work Unit No.
9. Performing Organization Name and Address SCITRAN Box 5456 Santa Barbara, CA 93108		11. Contract or Grant No. NASw-2483
		13. Type of Report and Period Covered Translation
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Washington, D.C. 20546		14. Sponsoring Agency Code

15. Supplementary Notes Translation of "Kontaktlose Messeinrichtung zum kontinuierlichen Erfassen von Temperaturwerten auf rotierenden Teilen, besonders bei elektrischen Maschinen". AEG-Telefunken, Technische Mitteilungen, Vol. 63, No. 7, 1974, pp. 278-284. A74-22499.

16. Abstract

This paper introduces a universal measurement system by AEG-TELEFUNKEN designed for the continuous electrical and non-electrical properties. The measurement information is transferred without contacts from rotating parts to a stationary apparatus. The system consists of an active electronic installation on the rotating parts and a stationary electronic part. Electrical signals are available at the output terminals of the electronic part which can be used for display, remote display, recording, supply of limit value indicators, further processing in process computers, etc. The system has no maintenance nor wear and is designed for continuous operation. The system is described using the example of a temperature recording installation with three independent measurement points for the Neu-Ulm network coupling transformer of the German railways. The same considerations apply for systems for collecting other electrical and non-electrical quantities.

17. Key Words (Selected by Author(s))		18. Distribution Statement Unclassified - Unlimited	
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 22	22. Price

A CONTACTLESS MEASUREMENT SYSTEM FOR CONTINUOUS RECORDING OF TEMPERATURES ON ROTATING PARTS, ESPECIALLY IN ELECTRICAL MACHINES

W. Raasch and D. Schein

1. BASIC CONSIDERATIONS FOR TEMPERATURE MEASUREMENT SYSTEMS /278*

1.1. Classification of systems

The reason for developing the measurement system was the necessity for accurately measuring temperature values in the rotating parts of electrical machines. The requirement for extensive automatic operation of the installations and the desire for the highest possible lifetime of electrical machines requires a third system which makes available the characteristics for optimizing the operation of the installation (Figure 1) [1, 2] in addition to the connection systems for control and regulation and the surveillance and protection systems.

If we consider the temperature measurement in particular, /279
we must distinguish three types: the limit value systems and the continuously operating systems (Figure 2).

1.2. Limit value systems

These systems are suitable for surveillance and for the protection of machine installations. As soon as the temperature goes above or below a limiting value, a signal is generated.

* Numbers in margin indicate pagination in original foreign text.

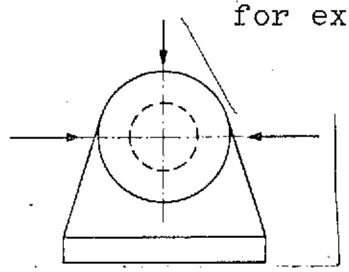


Figure 1. Operational systems for an electrical machine

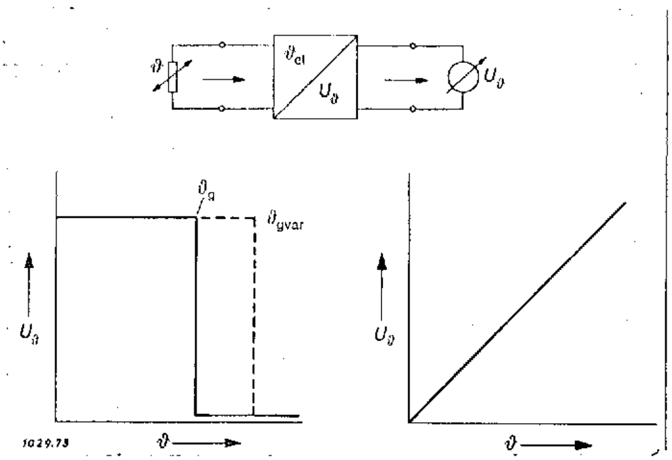


Figure 2. Behavior of the temperature measurement systems

Left: Limit value system
Right: Continuous working system
ϑ_G Limit temperature

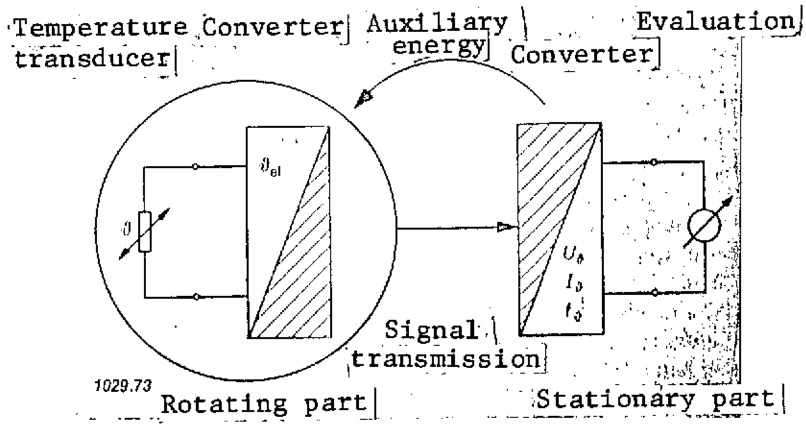


Figure 3. Rotating temperature measurement system

Temperature dependent semiconductor resistor sensors are used for relatively accurately specified limit temperature values, which change their electrical resistance almost discontinuously over a narrow temperature range (cold conductor sensor or PTC* resistors). This principle is used in the AEG motor protection system for limit temperature determination in non-moving parts, for example, winding temperature surveillance in electrical machines.

If temperature limit values are to be measured in rotating parts, especially in armature windings of electrical machines with critical contacts, the surveillance system Geaphyl® is used which makes it possible to monitor several measurement points with respect to a limit temperature value without the use of contacts [3-6].

1.3. Systems for continuous temperature measurement

These systems are electrical and use various types of temperature sensors, for example, thermoelements, resistance

* PTC: Positive temperature coefficient.

thermometers or semiconductor elements, such as hot conductors. Often platinum thermometers according to DIN 43 760/9.68 [7] are used in the stators of electrical machines. The resistance value is a measure for the temperature value of the sensor.

Depending on the system, an auxiliary current is used for the sensor circuit (direct current or alternating current). The electrical circuit can be designed in various ways. For example, according to the compensation method, according to the measurement bridge system, or according to the current-voltage system.

The electrical output signal can be made available in analog or digital form depending on the model. Systems for measuring temperatures in rotating parts must be amply protected in the sensor circuit against noise and against electrical and/or magnetically coupled foreign signals. This requirement is satisfied by the measurement system for contactless temperature measurement transmission [8], the structure of which is shown in Figure 3.

For contactless transmission of temperature information from rotating parts to the stationary part, it is necessary to use measurement value transformers (shaded part in Figure 3), which can be called the rotating transmitter and the stationary receiver, using simplified notation.

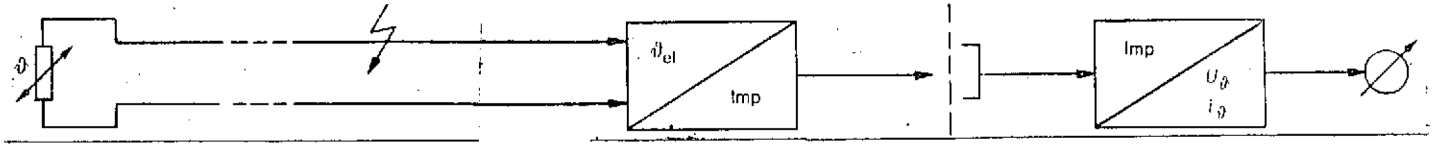
2. THE FUNCTIONAL PRINCIPLE

Because of the sensor temperature, an electrical temperature signal is produced. If we have a passive temperature sensor, for example, a resistance thermometer, then it is necessary to have an auxiliary energy supply in order to obtain an electrical signal corresponding to the sensor temperature.

Rotating part →|← Stationary part

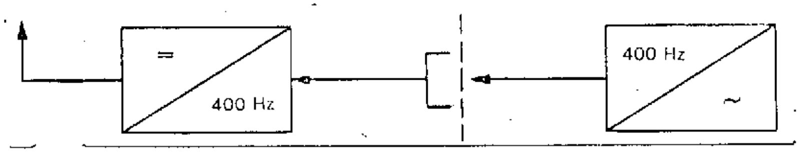
SENSORS	SENSOR CIRCUIT	SIGNAL PREPARATION	SIGNAL TRANSMISSION	SIGNAL RECOVERY	EVALUATION
(i.e.: Temp measurement) Thermoelement PTC* sensors NTC** sensors Capacitive sensor *PT 100 sensors*	Carrier freq. *Direct signal*	(Modulator) Direct signal AC amplitude Frequency (Sine;rectang. *Pulse frequency*	Galvanic Optical Capacitive Radio *Inductive*	(Demodulator) *Forced* (Det. by modulator)	Display instr. Recorder *Arbitrary* Useful Signal

Noise signal



SENSOR CALIB.	NOISE FILTER	MODULATOR CALIBRATION	TRANSMISSION	CALIBRATION	SIGNAL
Yes *No*	No *Yes*	Yes *No*	Dependent on position *Not dependent on position*	No *Yes*	*Constant voltage* *Constant current* Pulse (possible)

SENSOR AND SENSOR CIRCUIT	ROTATING ELECTRONICS	STATIONARY ELECTRONICS
...depending on temperature measurement range	0° C...+ 100° C working range -20° C...+ 100° C functional range	0° C...+65° C working range -20° C...+65° C functional range



ROTATING NETWORK UNIT — MAGNETIZATION GENERATOR

* PTC Positive Temperature Coefficient
** NTC Negative Temperature Coefficient

Figure 4. Characteristic data for the contactless measurement value transmission system of AEG-TELEFUNKEN (the characteristics produced successfully in this system are indicated by italics).

The electrical temperature signal is so small in most cases that it is necessary to amplify the signal. During signal processing it is converted into another electrical form, which can be used for any kind of further processing. This can be in the form of a voltage U_ϑ, a current I_ϑ or a digital representation for example, a frequency f_ϑ.

2.1. Special features of the measurement system

The requirements on the temperature measurement value collection system to be applied for rotating parts, in particular in electrical machines which will guarantee continuous operation, can be distinguished in the decision diagram (Figure 4).

In this diagram, the characteristics which have been realized in the system being described are indicated by italics.

/280

Sensors (PT-100 thermometer)

The use of standardized sensors makes it possible to exchange them without a recalibration of the apparatus. The design of the temperature sensors is arbitrary. The temperature sensors therefore do not represent special components of the measurement system.

Sensor circuit

The line location in the sensor circuit is not critical. It is possible to use twisted lines which will guarantee noise-free operation of the measurement installation because noise filters are located in the sensor circuit which keep foreign voltages away from the modulator.

Signal processing (rotating part)

The rotating measurement electronics is protected against foreign disturbances by means of a steel sheet housing. The electronic components are mounted on a printed circuit. The components are arranged so as not to be disturbed by centrifugal force. The complete encapsulation of the building block allows high centrifugal force and vibration loads.

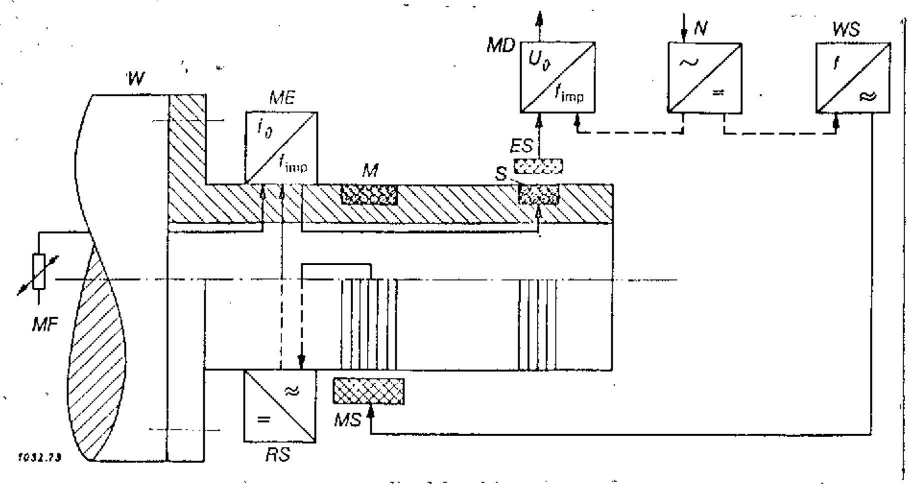
There are no adjustment controllers in the rotating part which would produce contact transfer disturbances. The entire measurement chain is exclusively calibrated at the demodulator, that is, in the fixed stationary part.

The output signal of the modulator is a frequency-modulated pulse sequence. In principle, the modulator is an analog-digital converter which also contains an amplifier so that the primary coil (rotating transmitting coil) of the rotating transmitter can be supplied with sufficiently strong pulses (Figure 5).

Signal transmission

Only short pulses are supplied to the inductive rotational transmitter, so that in spite of the high pulse energy, the auxiliary energy requirement of the modulator is small.

The pulse-shape signal energy produces a high transmission certainty of the signals to the stationary apparatus. By using a frequency modulated signal, it is possible to have error-free measurement value transmission even when the transmission conditions of the rotating transmitter fluctuate or change over a wide range. Since the rotational transmitter is independent of the shaft position, the measurement apparatus can be used over a wide rpm range and for zero rpm (shaft standing still).



W Shaft of the machine rotor
MF Measurement sensor (platinum resistance thermometer PT 100)
ME Measurement electronics
M Auxiliary energy coil
S Transmission coil
ES Reception coil
MD Measurement value demodulator
N Net unit
WS Alternating current auxiliary energy generator
MS Magnetization coil
RS Rotating current supply installation

Figure 5. Contactless temperature measurement system with special measurement shaft

Signal recovery

The stationary secondary coil (reception coil) of the measurement rotation transmitter directs the induced pulses to the measurement value demodulator which operates as a digital-analog converter. The adjustment controllers for calibration of the entire measurement chain and for each channel are located along a single exchangeable printed circuit of the mechanical building block system INTERMAS| [9].

The output signals are available in the form of imposed voltage values and current values independent of each other, which can be used for further processing. If desired, it is also possible to output the modulated pulse frequency magnitude.

The correspondence of the temperature value and the output signal value can be changed over a wide range, for example, a measurement range between zero to 150° C.

Auxiliary energy

In principle, the rotating modulator group can be supplied with batteries. /281

Rotating current supply installation

For continuous operation there is a rotating current supply installation for a maximum of three modulators. This installation has the same external shape and weight as the modulator. In this way the rotating part consisting of the modulators and the current supply installation has little unbalance.

Energy transfer

The auxiliary energy is supplied by an alternating current generator through an inductive rotational transfer unit to the rotating current supply system.

Alternating current generator

The alternating current generator consists of a low frequency oscillator whose frequency and amplitude signals can be changed over a small range in order to make adjustments. It also includes a low frequency power amplifier.

Figure 6. Adjustment component

Left: Distance gauge for rotational transmitter
Right: Calibration and control unit

Line power supply

The power supply supplies the entire measurement system with the required auxiliary power. Depending on the type, the electrical energy can be taken from the local alternating current line or from other supply sources.

Calibration unit

A calibration unit and a distance gauge for setting the air gap of the rotational transfer units is included for convenient calibration and adjustment of the system (Figure 6).

2.2. Circuit principle and method of operation

The transformation of temperature-dependent resistance changes of the platinum resistor thermometer PT 100 into a voltage change is done using a constant preliminary current (Figure 5).

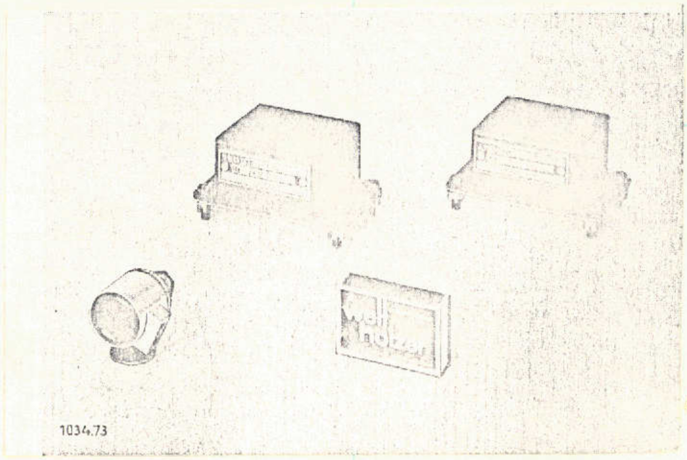


Figure 7. Reception coil (left), rotating current supply installation (center) and measurement value electronics (right)

The voltage change at the sensor is converted to an almost proportional pulse frequency change in the rotating measurement electronic unit. The output signal is amplified until the primary coil (the rotating transmission winding) of the measured value rotational transfer unit can be supplied directly. The measurement electronics are installed in a small steel sheet metal housing (Figure 7).

The current pulses in the rotating primary coil (transmission coil) of the inductive rotational transfer unit produce voltage pulses in the stationary secondary winding (reception coil), which are then further processed in the measurement value demodulator. They are available as outputs in the form of voltage, current or pulse frequency values which are proportional to the temperature.

The measurement value demodulator which has socket pins also contains the adjustment control unit for the threshold value level, zero point and final temperature value. It also contains the auxiliary group for controlling the operation, which consists of a switching relay and an optical display (Figure 8).

In order to provide the auxiliary energy for the rotating measurement electronics, there is a further inductive rotational transfer unit. An alternating current magnetization coil transfers energy which is made available by the power amplifier from the stationary part to the rotating secondary winding (auxiliary energy winding). It then supplies a rotating supply unit which /282 provides electronically stabilized direct voltages for current supply of the rotating measurement electronics as output quantities.

2.3. Calibration

The calibration of the measurement system of operational systems is carried out when the shaft is standing still. The later control calibrations are also done under these conditions. It is only necessary to adjust the rotational transfer units and to carry out a simple electrical calibration. This electrical calibration has the purpose of exactly adapting the output voltage range or current range to the temperature measurement range. For this purpose, the installed resistance thermometers are disconnected. Instead of them, a calibration and control unit (Figure 6) is connected which contains precision resistors corresponding to the final temperature range values, as well as several intermediate values.

3. STRUCTURE OF THE SYSTEM

The temperature measurement system for continuous operation consists of the following parts:

A rotating part with one set of measurement electronics per measured value and a current supply installation for a maximum of three measured values each.

A stationary part with a reception coil and a measured value demodulator for each measured value, as well as an alternating current magnetization coil, an alternating current generator and a power supply unit for three phase alternating current 380 V, 50 Hz.

The stationary conducting plates with socket pins as well as the individual groups are designed according to the mechanical INTERMAS [9] structure system. Appropriate housings, magazines and inserts from this construction group are available.

The components which are not tied to the system are the temperature sensors, their leads and additional line terminals, as well as the special auxiliary parts for installing the electronic components on the rotating part.

(Illegible) depending on the applications, these can be very different. Therefore, it would not be appropriate to prescribe a number of construction type or to force a certain type of construction on the user. Because the rotational transfer units are not critical, it becomes possible to establish directives according to which these windings can be made. /283

3.1. Directives for the design of the transmission coil

The transmission coil supplied by the measurement electronics constitutes the primary rotational transfer unit which is magnetically coupled with the stationary secondary winding (reception coil). A single or double shaft winding has been found to be appropriate for the transmission coil; in order to protect it against mechanical abuse, it can be recessed into the carrier shaft.

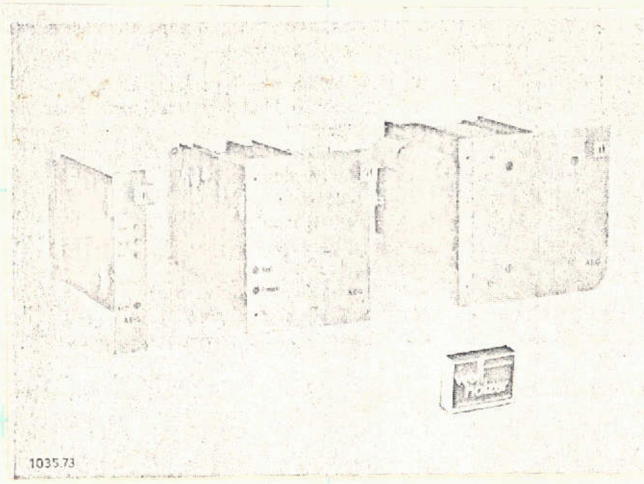


Figure 8. Measurement value demodulator (left) alternating current generator (center) and net unit (right)

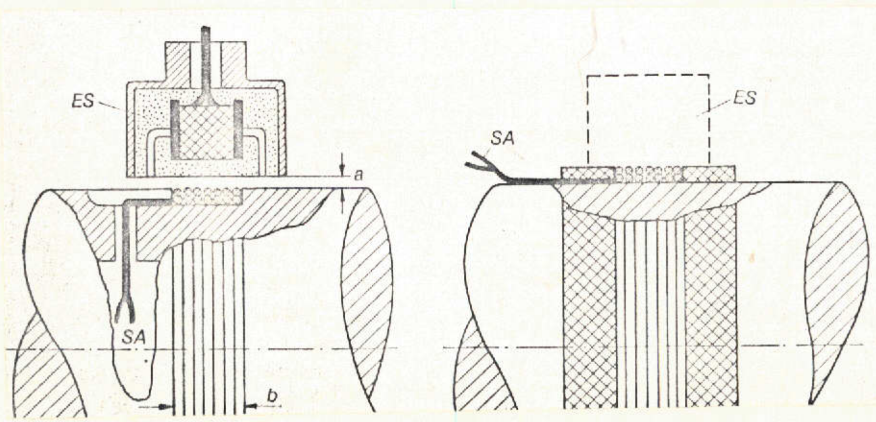


Figure 9. Rotating measurement value transmitter

Left: Imbedded coil; version for constant operation.
Right: Loose winding; for temporary installation of a temperature measurement installation for short time operation, it can be done with a small amount of material.

ES Reception coil
SA Coil connections

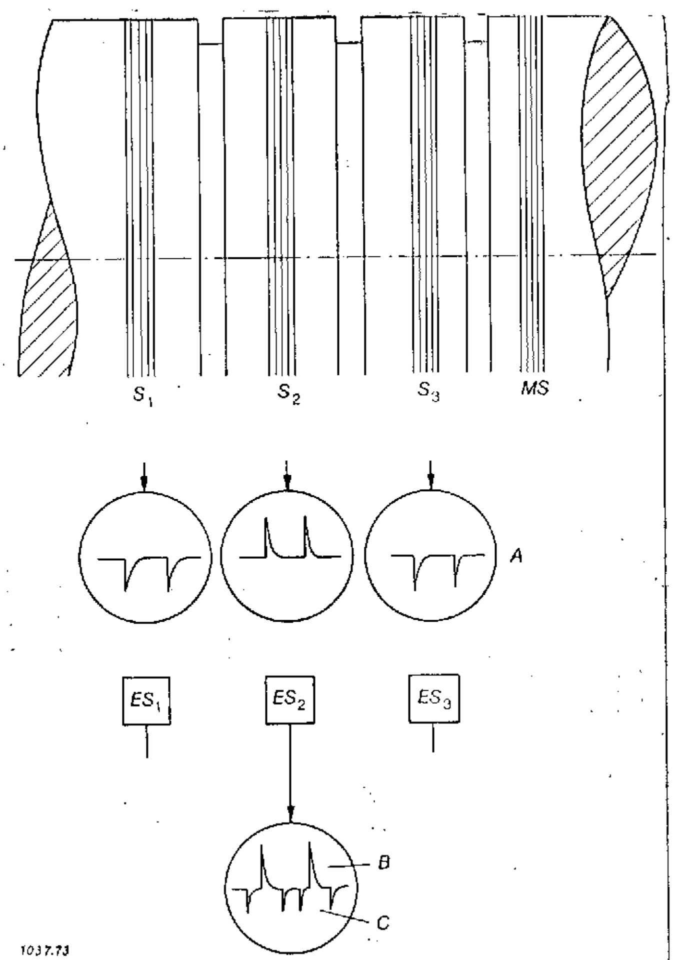
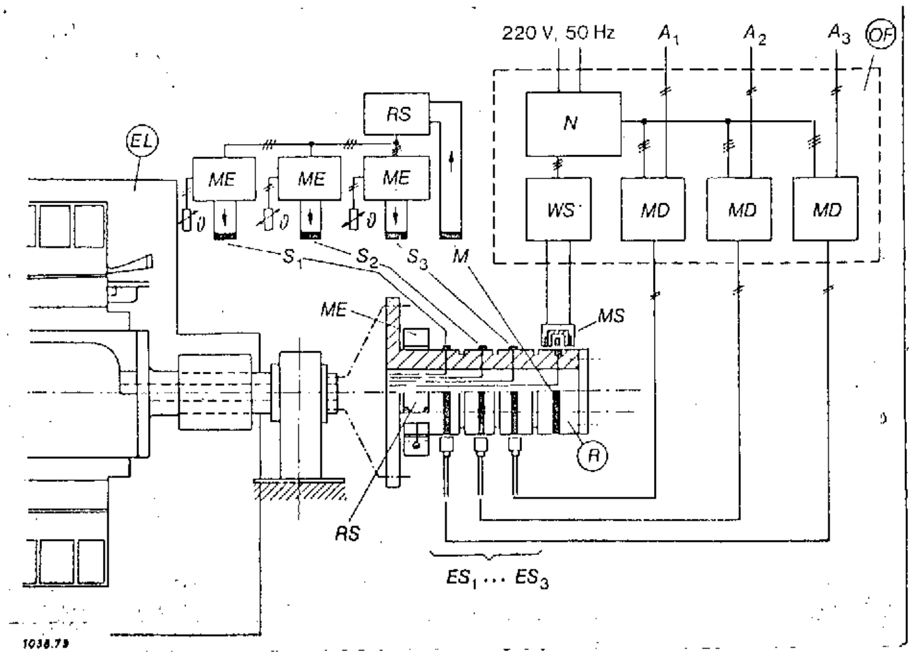


Figure 10. Transmission coils for multichannel operation

$S_{1,2,3}$	Transmission coil
MS	Auxiliary energy coil
$ES_{1,2,3}$	Reception coils
A	Pulses in the transmitting coils for alternate polarity
B	Measurement value pulses
C	Noise pulses



R	Rotating part	OF	Fixed part
ME	Measurement electronics	MS	Magnetization coil
RE	Rotating current supply installation	WS	Alternating current generator
		N	Net unit
$S_{1,2,3}$	Transmitting coils	MD	Measurement value demodulator
M	Magnetization shaft winding	$A_{1,2,3}$	Temperature signal outputs
		$ES_{1,2,3}$	Reception coils
ϑ	Resistance thermometer	EL	Electrical machine

Figure 11. Temperature measurement system for three measurement points in the rotating part

Figure 9 gives an example of the principle of the pulsed transfer using a transmission coil and a reception coil with a U-shaped magnetic receiver which is installed at only one point of the shaft circumference.

If only one measured value signal is transmitted, then there are no special requirements for the location of the transmission coil. In the case of multichannel operation, the transmission coils must be installed next to each other. It is possible to avoid a mutual coupling of the individual channels by changing the pulse polarity of adjacent coils and by maintaining

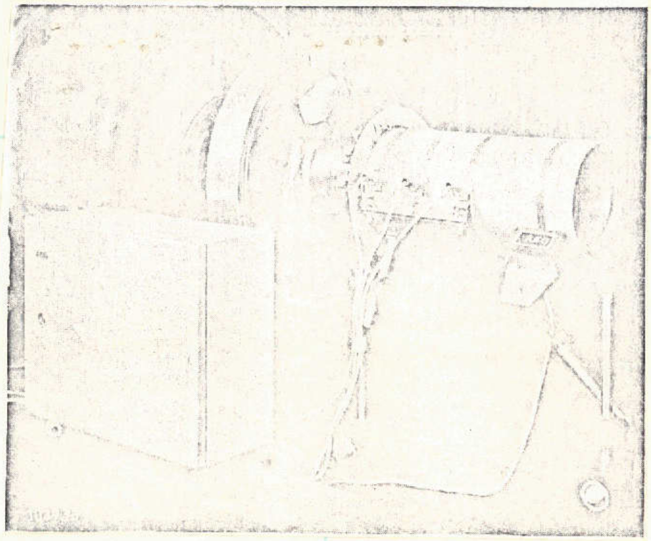


Figure 12. Installation of the measurement value transmission system for three temperature measurement points in the Neu-Ulm net coupling transformer (test configuration)

an axial minimum distance between the transmission windings and between them and the auxiliary energy winding (Figure 10).

3.2. Directives for the design of the auxiliary energy coil

The special design of the shaft winding is determined by the properties and requirements of each individual case (short time operation or continuous operation of the measurements).

A coaxial shaft winding which is directly applied to the shaft represents a simple and safe solution for the design of the auxiliary energy coil. There are instructions for the appropriate execution of the shaft winding which are available to the user.

(Illegible) Neu-Ulm

In order to measure three independent temperature values in the rotating part of the Neu-Ulm net coupling transformer AEG-TELEFUNKEN has developed a measurement system with a special measurement shaft. This measurement shaft is arranged at the end of the machine group. Figure 11 shows the interaction of the individual parts and how they are switched together. The mechanical structure and arrangement of the groups is shown in Figure 12.

By concentrating the measurement system at an easily accessible point of the machine group it becomes possible not only to deliver a completely tested system to the construction site, which results in fast installation times, but also there are essential advantages for servicing the installation. When maintenance work is required for the machine group, the measurement shaft can be removed entirely. Only the electrical connection leads to the temperature sensors must be disconnected. Also the reassembly is simple.

The housing with the stationary electronic installation can be installed at an appropriate location. This electronic part is connected with the reception coils and the magnetization winding using shielded measurement cables. The setting of the air gaps of the rotational transfer units is not critical and is only approximately done using a distance rule.

The system is convenient to use during installation, maintenance and calibration. Its reliability was very important to us. Operational experience with the units described has shown that it is possible to have a reliable temperature measurement in the rotating part [1] even when there are large noise levels, for example, caused by controlled and uncontrolled power rectifier circuits.

The principle of using only direct current in the temperature sensor circuits and thereby producing simple and effective noise removal components has exceeded all expectations regarding the resistance to noise. Even extremely long lines in the temperature sensor circuit produced a reliable operation of the temperature measurement system. Of necessity, these lines must pass through regions with strong electrical and magnetic fields. /284

Since the machine unit can be loaded by the electronic power regulation unit in a continuous way up to the thermal limit, it is necessary to continuously monitor the function of the measurement system in order to avoid any damages to the machines if the temperature measurement installation fails. This is why the operational monitoring installation of the temperature measurement system is connected to the subordinate disturbance signaling system of the entire installation so that failures can be immediately recognized (for example, auxiliary energy supply failure, sensor circuit interruption and sensor circuit short circuit).

The positive experience with the described measurement system for the continuous recording of measured values in rotating parts without the use of contacts makes it possible to use the measurement installation for other arbitrary applications. We primarily see the possibility of the electrical machines, which can be considered to have a critical rotor.

REFERENCES

1. Betz, H. The Neu-Ulm Line Coupling Converter, an Installation for Supplying Current to the German Railways. Techn. Mitt. AEG-TELEFUNKEN, Vol. 63, No. 7, 1973, pp. 249-253, 5 B, 13 Qu.

2. Holweck, P. Electronic Power Regulation of an Elastic Line Coupling Converter. Techn. Mitt. AEG-TELEFUNKEN, Vol. 62, No. 7, 1973, pp. 273-278, 7 B, 7 Qu.

3. Loocke, G. and D. Schein. Thermal Protection Device for Machines with Critical Rotors. Elektro-Anz. Vol. 22, 1969, pp. 232-234.

4. Loocke, G. and D. Schein. Geaphyl®, a Thermal Protection Unit for Machines with Critical Rotors. Techn. Mitt. AEG-TELEFUNKEN, Vol. 59, No. 1, 1969, pp. 38-40, 4 B, 5 Qu.

5. Thermal Protection Device Geaphyl® . Techn. Mitt. AEG-TELEFUNKEN, Vol. 62, No. 2, 1972, p. 89, 1 B.

6. Thermal Protection Device Geaphyl® for Rotor Monitoring in Direct Current Machines Techn. Mitt. AEG-TELEFUNKEN, Vol. 63, No. 3, 1973, p. 135, 2 B.

7. DIN 43 760/9.68. Electrical Temperature Measurement Devices; Basic Values of Measurement Resistors for Resistor Thermometers.

8. Raasch, W. and D. Schein. Contactless Measurement Installation for Continuous Measuring of Temperature Values on Rotating Parts, especially of Electrical Machines. Lecture during the INTERKAMA 1971, Düsseldorf.

9. Bohnenberger, W. and D. Hesse. INTERMAS, the Mechanical Construction System. Techn. Mitt. AEG-TELEFUNKEN, Vol. 62, No. 4/5, 1972, pp. 148-162, 34 B, 2 T, 25 Qu.

Translated for National Aeronautics and Space Administration under contract No. NASw 2483, by SCITRAN, P. O. Box 5456, Santa Barbara, California, 93108.